Improvement of Mesoscale Numerical Weather Prediction For Coastal Regions of Complex Terrain

Clifford F. Mass
Department of Atmospheric Sciences,
Box 351640
University of Washington
Seattle, Washington 98195
phone: (206) 685-0910, fax: (206) 543-0308, email: cliff@atmos.washington.edu,

Grant Number N00014-98-0193
http://www.atmos.washington.edu/

LONG-TERM GOALS

One goal of this effort is to improve the skill of mesoscale numerical weather prediction (NWP) over coastal regions of complex terrain and to evaluate the effectiveness of high-resolution NWP for civilian and military applications. Other important goals include understanding the structural and dynamical interactions that occur as synoptic weather systems interact with coastal terrain, and the nature of coastal gap flows and other meteorological phenomena associated with coastal orography

OBJECTIVES

The major scientific objectives of the project include the following:

* Evaluation of the value of mesoscale ensembles using both varying initializations and model physics.

* To complete an intensive verification of a large number of high-resolution mesoscale forecasts to determine mesoscale model skill for a variety of parameters. This work will not only quantitatively evaluate model skill as horizontal resolution is increased for the whole domain, but will determine whether certain areas are more predictable than others.

* To help determine the implications of a local mesoscale forecasting capability for regional Navy operational needs, and to help train Navy personnel in the use of high-resolution model forecasts.

* To study gap flow in and near coastal orography, as well as the interaction of synoptic disturbances with coastal terrain.

* To investigate the quality of model initialization over the Pacific of a number of modeling systems, and to determine how initialization quality affects forecast skill.

* To evaluate timing errors of troughs as they approach and interaction with the west coast of North America.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2001		**00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE
Improvement of Mesoscale Numerical Weather Prediction For Coastal Regions of Complex Terrain

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Atmospheric Sciences,,Box 351640,University of Washington,,Seattle,,WA, 98195

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
One goal of this effort is to improve the skill of mesoscale numerical weather prediction (NWP) over coastal regions of complex terrain and to evaluate the effectiveness of high-resolution NWP for civilian and military applications. Other important goals include understanding the structural and dynamical interactions that occur as synoptic weather systems interact with coastal terrain, and the nature of coastal gap flows and other meteorological phenomena associated with coastal orography

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

Twice-daily forecasts of the Penn State/NCAR model for the west coast of North America have been made over the past several years at horizontal resolutions of 36, 12 and 4 km. These forecasts have been compared over the Northwest with a very dense set of mesoscale observations, taken from over a dozen separate networks.

An ensemble prediction system has been created that runs the MM5 at 36 and 12-km resolution eight times: five runs with different initializations and lateral boundary conditions (NCEP AVN, ETA, MRF and Navy NOGAPS and Canadian GEM model) and three additional physics diversity runs (varying PBL schemes, microphysics and cumulus parameterizations). These 8 runs are made daily (0000 UTC cycle) and are being carefully verified against regional observations. The skill of the ensemble mean and the relationship of forecast skill and spread have been examined in great detail

COAST field experiment cases have been analyzed using both numerical simulation and observations, including the radars/flight level instrumentation of the NOAA P3 aircraft. One case deals with a strong Pacific front that crossed the coastal terrain of British Columbia and Washington. Another is the 12 December 1995 event in which a deep low crossed the coast near Tatoosh Island.

We are also well into a detailed study of the dynamics and modeling of gap flow, with particular attention to the Columbia River Gorge. Observational analyses are being made for a number of cases, using both a collection of surface networks and ACARS aircraft data from flights approaching and leaving Portland. We have also studied such gap flows numerically.

Another major project has been to evaluate the strength and timing errors of troughs approaching the U.S. west coast over a several year period. We have developed objective algorithms for determining MM5 and NCEP Eta model timing errors for a collection of 8 buoys over the eastern Pacific and along the coastal waters.

The fidelity of microphysical schemes used in mesoscale models is being evaluated. During the past year, the first part of a major field experiment to improve microphysical schemes (IMPROVE) took place over the coastal waters of the Northwest. Navy reservists played an important role in this project, taking crucial additional radiosonde measurements in the coastal zone.

WORK COMPLETED AND RESULTS

Specific ONR-supported accomplishments during the past year includes:

1. Several detailed studies of the interaction of synoptic fronts with coastal terrain were completed. For example, using data from the NOAA P3 aircraft and conventional observations, the interaction of the COAST IOP2 front with the Olympics and Cascades was documented and successfully simulated (Chien et al 2001). An ongoing study now being completed describes the coastal effects of a major cyclone (12 December 1995) as it approached and crossed the coastal mountains.

2. Several years of high resolution (36-12-4 km horizontal resolution) mesoscale forecasts by the MM5 over the Pacific Northwest have been verified in detail and several papers describing the effects of varying resolution in coastal terrain have been published or submitted (Colle and Mass

1999, Colle et al 1999, Mass et al 2001). Using conventional skill scores, a clear improvement in precipitation forecasts was apparent going from 36 to 12 km, with additional skill at 4 km when the synoptic flow is well forecast. A comprehensive paper describing the effects of resolution on major parameters has been accepted for publication in the *Bulletin of the AMS*. Detailed evaluation of real-time precipitation forecasts and limited microphysical data from the COAST field experiments has revealed significant deficiencies in microphysical schemes over coastal terrain. This work has stimulated the upcoming IMPROVE field experiment, that will collect both state and microphysics data for both synoptic and orographic atmospheric features.

3. The 8 member mesoscale ensemble system has been created, made operational, and its output is available in real-time on the web. We have put into place a verification system and will be analyzing the results of a full winter. Our initial evaluation shows that mesoscale detail is apparent in the ensemble mean and that the ensemble mean has generally been more skillful than any individual member. Even more important, we have found that the ensemble system is capable of forecasting model skill.

4. A high level of interaction has been fostered between the UW group and Navy operations personnel at Whidbey Island NAS. This interaction has included the provision of the MM5 real-time forecasts, forecast discussions over the telephone, and several meetings with Whidbey personnel. Substantial interaction has also occurred with NRL Monterey, and particularly the mesoscale modeling group.

5. Substantial progress has been made in observational and modeling studies of the flow through the Columbia River Gorge. The Gorge is an ideal test bed for the study of gap flows due to its simple geometry and substantial data assets. Our work has revealed improved simulations as horizontal resolution is increased to .3 km. Figure 1 below shows the surface wind fields from a high-resolution (.44 km) simulation. Note how the low-level winds are greatest over the western exit of the Gorge. Figure 2 shows a corresponding vertical cross section in which the acceleration of the low-level winds is coincident with the collapse of the depth of the cold easterly flow.

6. Our analysis of trough timing errors has revealed mean absolute timing errors of 2-4 hours for most locations along the west coast, with larger timing error near the substantial terrain of northern California/southern Oregon. This work has been accepted for publication in Monthly Weather Review.

7. Our evaluation of various model initializations reveals substantial differences in initialization quality over the Pacific, with the NCEP MRF or AVN models generally being the best. The correlation between Pacific initialization quality and forecast skill downstream is significant along the Pacific coast, but decreases over the continental U.S. Summary results are available on-line and a summary paper is now being written.

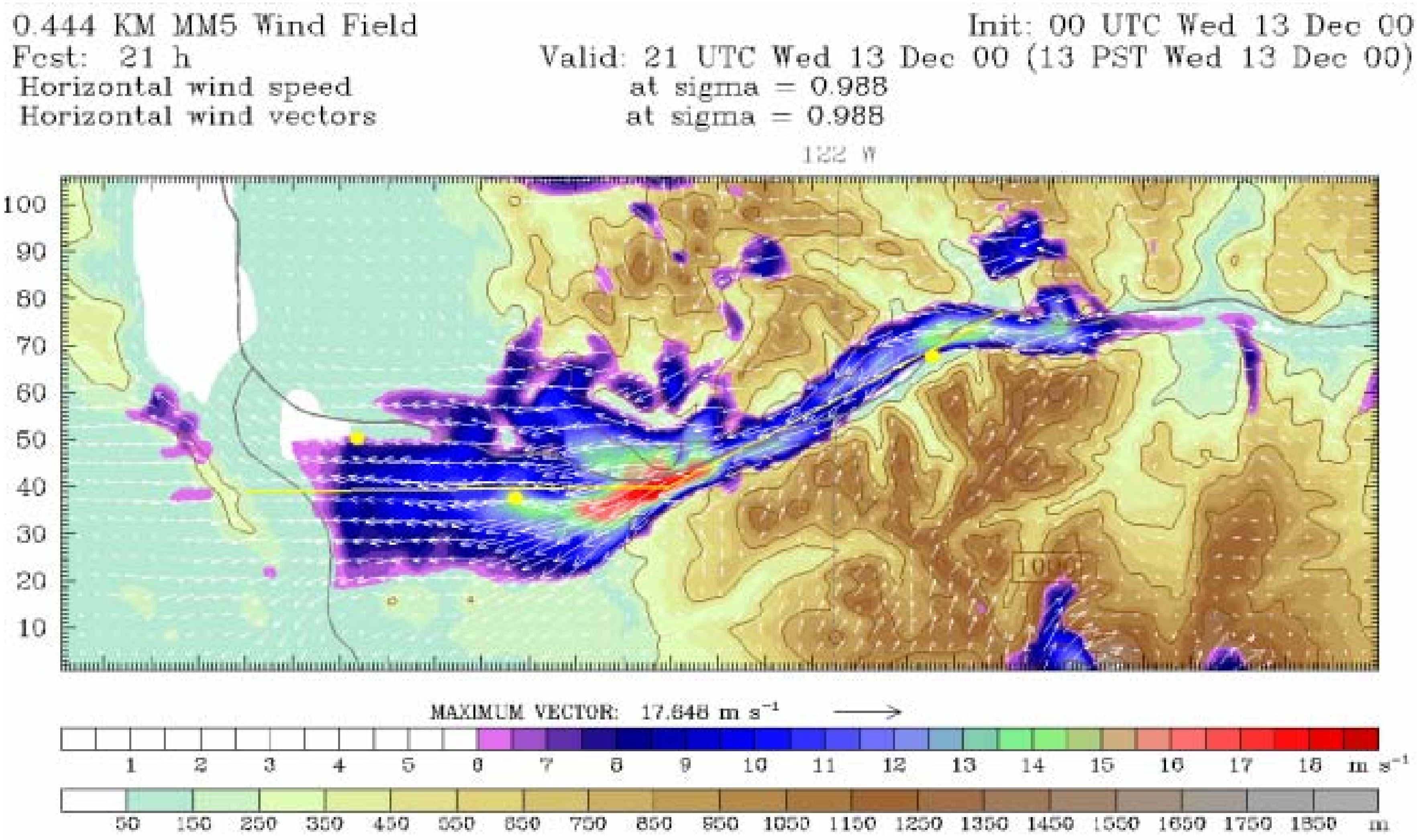

Figure 1: Plot of wind vectors and wind speed at 20 m above the surface from an MM5 21-h forecast in the Columbia River Gorge. Note that the strongest winds, exceeding 16 ms-1, are at the western exit of the Gorge. The topography is shaded in brown tones.

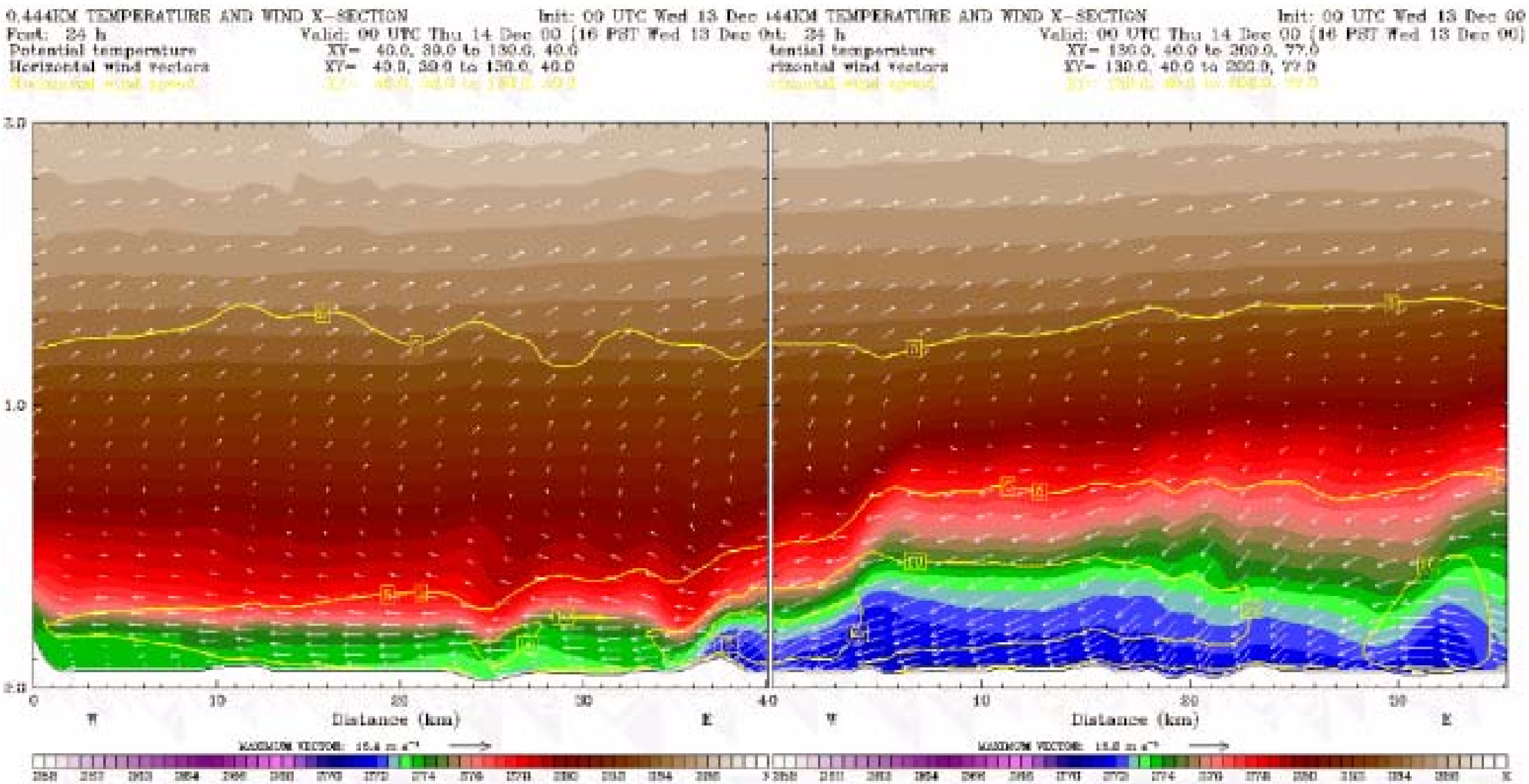

Figure 2. An east-west vertical cross section along the Columbia River Gorge from a 24-h MM5 simulation. Shading shows potential temperatue and wind are indicated by vectors. Note how the depth of the cold air originating in eastern Washington collapses over the western exit of the Gorge. Winds greatly increase in this region.

IMPACT/APPLICATIONS

This work provides the best documentation to date of the influence of horizontal resolution on the fidelity of regional numerical weather prediction, describing where the point of diminishing returns appears to be. The ensemble work is probably the cleanest test of this concept yet for short-range forecasts. The project's research also substantially clarifies the structural evolution and dynamics of a number of orographically trapped features along the west coast of North America and demonstrates the potential of high resolution numerical modeling for warm and cold season events. Finally, this research provides detailed understanding of the mesoscale structures resulting from the interaction of the synoptic scale flow and coastal orography.

TRANSITIONS

Judged by citations, the above work has had a substantial influence on other groups involved in the study of coastal circulations in complex terrain. The predictions produced by this effort have been used by local Navy meteorologists in the Northwest (e.g., Whidbey, Bangor), and our experiences will be used in the development of training materials for Navy forecasters. The work on gap flows is being used in the Navy mesoscale primer.

REFERENCES

Publications sponsored in total or part by this grant during the last year include:

Grimit, E. P., and C. F. Mass, 2001: Initial results of a mesoscale short-range ensemble forecasting system over the Pacific Northwest. Accepted in Wea. and Forecasting

Colle, B.A., C. F. Mass, and D. Ovens, 2001: Evaluation of the timing and strength of MM5 and Eta surface trough passages over the eastern Pacific. Accepted in *Weather and Forecasting*

Chien, F.-C., C. F. Mass, and P. J. Neiman, 2001: An observational and numerical study of an intense land-falling front along the northwest coast of the U.S. during COAST IOP2. *Mon. Wea. Rev*., **129**, 934–955.

Mass, C., D. Ovens, M. Albright, and K. Westrick, 2001: Does Increasing Horizontal Resolution Produce Better Forecasts?: The Results of Two Years of Real-Time Numerical Weather Prediction in the Pacific Northwest. Accepted in Bull. Amer. Meteor. Soc.

Colle, B. A., C. F. Mass, and K. J. Westrick, 2000: MM5 precipitation verification over the Pacific Northwest during the 1977-1999 cool seasons. *Weather and Forecasting*, **15**, 730–744.

Davis, C., S. Low-Nam, and C. F. Mass, 2000: Dynamics of a Catalina Eddy revealed by numerical simulation. *Mon. Wea. Rev*., **128**, 2885-2904

Colle, B. A. and C. F. Mass, 2000: High-resolution observations and numerical simulations of easterly gap flow through the Strait of Juan de Fuca on 9-10 December 1995. *Mon. Wea. Rev.*, **128**, 2363-2396

Colle, B. A. and C. F. Mass, 2000: The 5-9 February 1996 flooding event over the Pacific Northwest: sensitivity studies and evaluation of the MM5 precipitation forecasts. *Mon. Wea. Rev.,* **128**, 593-617